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Sustainable Alternative Routes versus Linear Economy and Resources Degradation in Eastern Romania

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Abstract: This paper reveals the linear economy contribution to resource degradation and environmental pollution in eastern Romania that could further feed environmental crimes and conflicts, such as in the Pungesti shale gas case. Preservation of material and water resources in the region is required through various circular mechanisms under a cross-sectoral approach including solid waste as a material resource for industry and agriculture; wastewater treatment and water reuse; composting and organic agriculture; and using renewables. Six non-conflictual sustainable alternative routes related to circular economy mechanisms, water preservation, and to the clean energy transition are proposed in this paper, which are further examined through key statistics and indicators, current best practices, and local development pathways in both urban and rural communities.

Keywords: linear economy; circular economy; water resources; waste management; renewables; composting

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1. Introduction

Improper management and exploitation of natural resources lead to pollution, poverty, and geographical inequalities at the local or regional level [1]. These factors feed environmental conflicts around the world [2]. A linear economy is based on unsustainable mechanisms such as the extraction of raw materials for industry; energy sources based on fossil fuels, water, and soil resource depletion [3,4]; consumer society; and landfill-based waste management systems [5]. This economic system is obsolete in the face of climate change, resource scarcity, and the socio-economic inequalities that threaten the world. In the context of the Sustainable Development Goals (SDGs) and Agenda 2030, the shift from a linear economy to sustainable alternatives is imperative. Higher demand for resource materials, energy, and food increase the environmental footprint of cities. From around the 100 billion tons of material that feeds the global economy in a year, only 8.6% is used in circular loops [1]. Therefore, the EU supports the transition of Member States towards the circular economy approaches, enacting an ambitious plan in this direction [6]. However, this path of transition is complex and requires, in addition to investment in infrastructure and cohesion efforts between old and new EU members, the involvement of various stakeholders and the participation of the community [7].

Besides resource materials, the water consumption required by agriculture, industries, and municipalities threaten freshwater resources in Europe. Around 33% of the population was exposed to water stress conditions in 2015 [8].

Both material and water resources has fed the linear economy, generating large amounts of waste, wastewater, and sludge that pollute the natural environment without closing the loops. The same quality standards for waste and wastewater management services are required across all EU regions to achieve a circular economy transition.

In reducing national and regional gaps, the urban–rural disparity is a real challenge for transition economies in Eastern Europe, including the public utility sector [9,10]. In Romania, the capital city and the larger urban areas are emerging economies compared to smaller towns and distant rural communities, which are exposed to poverty and marginalization [11]. In Eastern Romania, the larger urban and surrounding areas have to tackle an emerging trend of the construction sector (Iasi, etc.) for residential and commercial purposes or industrial activities (e.g., Galati) that require natural resources for building materials. Urban populations are exposed to air, water, and waste pollution. Remote communities are exposed to pollution due to the lack of services or inefficient basic services in, e.g., sanitation, waste collection, water and sewage systems, and road infrastructure [12,13].

Agriculture is the key economic development route of the rural settlements in the study area but the rural population also relies on subsistence agriculture close to households. Agricultural land is highly fragmented and affected by soil erosion, especially in the hilly regions which are also exposed to natural hazards or environmental pollutions [14–16]. Agricultural, industrial, and household activities have water demands that could decrease the availability of freshwater resources under climate change conditions in Eastern Romania. Eurostat monitors the water resource pressure through the water exploitation index (WEI +), which refers to water abstraction as a percentage of the freshwater resource [8]. This indicator could be used at the national and sub-national level, and could be applied for the Siret-Prut hydrographic network in eastern Romania.

Therefore, this paper aims at a cross-sectoral analysis of resource degradation through linear economic mechanisms to environmental conflicts (e.g., Pungesti shale gas), resource degradation, or environmental pollution through improper waste, wastewater, and water and agricultural management practices in a peripheral EU region. This work aims to identify six conflict-free sustainable alternatives supported by the local best practices to promote the transition to clean energy; to the responsible management of water resources; to circular mechanisms and to a sustainable agri-food sector in the study region.

2. Materials and Methods

2.1. Study Area

This paper focuses on Eastern Romania, which is comprised of four counties, namely Botosani, Iasi, Vaslui, and Galati. Several socio-economic indicators at the county level were examined through a WEB-GIS portal that aimed to reveal the regional inequalities in Romania and some key indicators for Eastern Romania are revealed in Table 1 [17].

Table 1. Socio-economic indicators in Eastern Romania.

Socio-Economic Indicators	Botosani	Iasi	Vaslui	Galati
Total resident population (number of inhabitants), 2018	385,268	791,753	379,987	510,865
Rural resident population (number of inhabitants), 2018	227,944	425,086	224,869	232,868
Wage earners (2019%) to population aged 20–65	20.9	29.7	18.1	29.7
Employment rate (%) of labor resources (2018)	57.4	55.7	55. 9%	56.1
School dropout rate (%) (2017)	3.3	2.3	3.1	2.3
External migration (number per 1000 inhabitants), 2015–2019	4.9	9.3	7.9	8.7

Source of data: National Institute of Statistics and [17].

These counties overlap on the Siret-Prut hydrographic network, which is further examined in the water resources section. The Iasi and Galati counties are characterized by the largest urban areas (Iasi and Galati county capital cities) with increasing tertiary (Iasi city) and industrial sector activity (Galati city) compared to the Botosani and Vaslui counties, which have dominant rural features reliant on the agricultural sector.

The cluster analysis based on socio-economic indicators performed by Fina et al. [18] revealed that the Botosani, Vaslui, and Galati counties are rural and old industrial regions compared to Iasi county, which is classified as a dynamic urbanized region due to the development hub of Iasi city. The presence of universities reflects the highest share of employees in knowledge industries (5.07%) in Iasi county, but the employment rate of labor resources and wages is lower in eastern Romania compared to center or western regions [18]. Distant rural communities from larger cities are prone to poverty and underdevelopment, thus favoring the emigration of labor resource abroad to other EU countries (Spain, Italy, etc.). The rural population is prevalent in the Botosani, Vaslui, and Iasi counties (>50% of total resident population), while not for Galati county (45.5%). Rural regions and towns need better connection to public utilities and road infrastructure to attract future investments in the region.

Sustainable agriculture practices provided by small and middle-sized farms could be a key development route for rural regions of Eastern Romania to stop emigration of human resources abroad and to strengthen local urban–rural relations in the agri-food sector.

2.2. Multi-Sectoral Approach

This paper aims to provide a comprehensive analysis of the resource degradation feed by the linear economy in waste, water, and agricultural management practices (Section 3). Primary resource exploitation could lead to regional conflicts due to related environmental concerns (e.g., Pungesti shale gas); therefore, six sustainable and non-conflictual alternatives (Subsections 5.1.–5.6), which could support both environment and local economies, must be further promoted, including a clean energy transition and water resource conservation efforts, taking into the consideration the current trends (1990–2018) and future water consumption demands in the study area (Section 4). The circular economy transition of Eastern Romania implies the development of equitable and sustainable local communities besides the resource recovery operations for industry or agriculture. This multi-sectoral approach is necessary to provide a holistic analysis, as shown in Figure 1, which must improve urban–rural relations under the sustainable regional development perspective. This approach could be applied in other Romanian regions or in transitional economies from Europe and beyond, where countries or regions are facing negative effects of linear economy and resource degradation that feed environmental crimes and conflicts, accelerating social injustice and geographical inequalities. Waste, water, and wastewater infrastructure development are critical to improve resource efficient activities in industry, agriculture, and at community level. The sustainable alternatives must be adjusted to the need of urban and rural communities.

However, these solutions must be supported by decision-makers in the study area and depend on financial resources available through EU funds as well as national and regional development projects. The circular economy transition involves multi-sectoral and complex interactions at regional and local levels; therefore, other possible solutions could emerge to complement the six non-conflictual sustainable alternatives proposed in this paper.

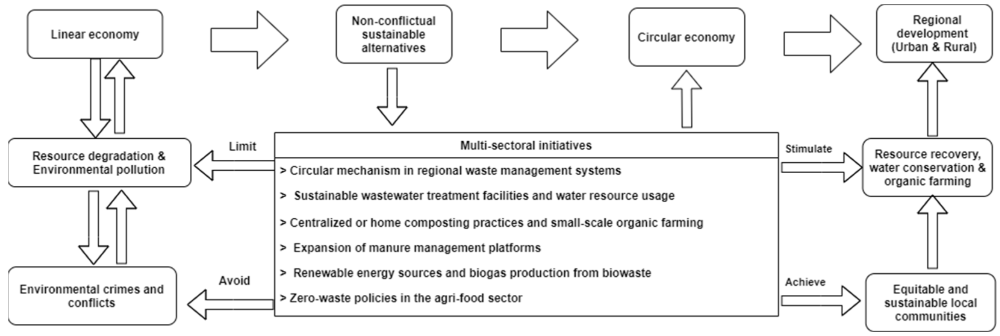

Figure 1. Six sustainable alternatives to limit resource degradation and environmental pollution in Eastern Romania under a multi-sectoral approach.

2.2.1. Waste Management and Circular Mechanisms

The linear economy causes natural resource depletion, aggravating resource scarcity issues in the study area. The circular economy becomes a core environmental policy at EU levels where municipal, industrial, and agricultural wastes are regarded as resources that must be reintegrated into cascading economic activities, thereby generating as less waste as possible [6].

Therefore, this paper performs a critical analysis regarding (i) waste management deficiencies in Eastern Romania related to waste and wastewater indicators as supported by a literature review as well as environmental reports and official statistics (National Institute of Statistics). (ii) Prospects of key waste streams with higher recovery and recycling potential are examined to support urban mining activities as opposed to traditional mining (construction and demolition waste, end-life-vehicles, and e-waste). (iii) Composting and energy recovery through biogas feed by biowaste (organic fraction of MSW, sewage sludge, agricultural wastes) is also discussed. Lastly, (iv) we review the best practices at the local level, which could catalyze the circular economy mechanisms, efficient water resource usage practices, clean energy transition, and sustainable agri-food sector activities in the study area.

2.2.2. Water Resources

Assessing the sustainability of water resources in a region can be achieved through a variety of methodologies. Given the specifics of the natural geographical conditions, the demographic, social, and economic evolution of that region, as well as the use of the water exploitation index (WEI), as developed by the European Environment Agency, are best suited to this type of analysis (Section 4). This index initially estimated at the country level and when subsequently applied at the river basin level, (WEI +) is calculated as the ratio of the average total annual freshwater demand and the average long-term freshwater resources (surface and groundwater) in a country, region, or river basin [19]. In this way, it is possible to assess how the total demand for water for various uses puts pressure on the water resources in the specific region. The average annual volumes of surface and groundwater that are available for economic and social exploitation are taken into account. Additionally, with the help of this index, it is possible to identify those areas that have a higher demand for water in relation to the available water resources and are therefore prone to water stress. The minimum period taken into account for the calculation of the WEI index is 20 years. The minimum warning threshold is 20%. If the values of this indicator are below 10%, the freshwater resources in the analyzed region are considered not subject to anthropogenic pressure.

If the values are between 10% and 20%, the water resources are considered subjected to reduced anthropogenic pressure, and values of the exploitation index between 20% and 40% indicate the existence of high anthropogenic pressure on the water resources. WEI values of over 40% indicate the existence of extreme pressure on water resources, with devastating impacts in the medium and long term. From the data transmitted between 1990 and 2016 by Romania to Eurostat, an index of the entire country was calculated. By applying WEI + (at the river basin level), the anthropogenic pressure on water resources in the entire eastern part of Romania for the period of 1990–2018 was estimated. The data used refers to the average annual volumes transported by the main rivers in the region and the estimated volumes at the level of groundwater bodies were provided by the Water Basin Prut-Barlad Branch.

3. Linear Economy and Resource Degradation in Eastern Romania

3.1. Linear Economy in Waste and Wastewater Management

3.1.1. Waste Management

The linear economy model supports the traditional waste management system, characterized by mixed waste collection and landfill or incineration without energy recovery of wastes generated by households, industries, and agricultural activities. Mixed waste collection areas prevail in the study across all four counties of Eastern Romania (Botosani, Iasi, Vaslui, and Galati) despite some improvements in recent years, mainly in larger urban areas, under the implementation of new regional integrated waste management systems.

The residual waste (humid and dry) cannot be further recycled and without mechanical–biological treatment plants (MBT), large amounts of waste are disposed of in landfills. Romania is still a landfill-based country and such sites are the main source of anthropogenic methane entering the atmosphere [20]. Conversely, Romanian cities relied on non-compliant landfills until 2017 when all these sites should have been closed and rehabilitated. The location of these sites in low-lying areas and near to human settlements pose environmental risks related to the air–water–soil pollution nexus [21]. In rural areas, wild dumps were the main waste disposal option until 16 July 2009 when such sites should have been closed and rehabilitated [22]. Rural dumps threaten soil and groundwater quality, and the extension of waste collection schemes is crucial for preventing environmental pollution and protecting public health [12]. Waste collection coverage is full or over 90% of the population in Botosani, Iasi, and Galati counties compared to Vaslui county, where this indicator covers 28.55% and only 10.22% in rural areas in 2018 [23]. This particular situation translates into large amounts of municipal waste being uncollected and uncontrolled for, thereby disposed of into the natural environment. The new regional waste management system from Vaslui county improved the rural waste collection coverage to 67% in 2019 [24]. Most of the municipal waste collected is disposed of in newly sanitary landfills after the closure of non-compliant landfills. In Galati county, the Tirighina landfill funded through the ISPA program servedGalati city and five additional communes, whereas the rest of the urban and rural municipalities do not have access to a regional sanitary landfill site. Therefore, a part of municipal waste collected (22 957 t in 2019) was transported and disposed of at the Rosiesti landfill site in Vaslui county, while in 2018–2019, around 25 600 t of waste was disposed of at the Muchea sanitary landfill from Braila county [25]. Source-separate collection of dry recyclables (plastic, paper/cardboard, metals, wood, and glass) and biowaste is still underdeveloped in all four counties, which inhibits the development of circular economy mechanisms in Eastern Romania.

3.1.2. Wastewater Management

At the global level, over 80% of the world's wastewater is released into the environment, without treatment for the pollution of marine and freshwater environments [4]. In Romania, wastewater generated by urban communities is poorly treated by outdated wastewater treatment plants (WWTPs), with primary and secondary stage treatments, and there is a poor connection to the sewage system in smaller urban areas or villages [26]. Additionally, industrial plants with their WWTPs are additional water pollution sources for nearby water bodies, where in effluents are discharged [27]. Consumption of water resources without proper sanitation facilities and wastewater treatment plants is a major environmental threat particularly in rural areas where drinking water sources are still reliant on wells [28]. As an example, wastewater discharged via Jijia catchment (Romania) and at Cahul (Republic of Moldova) increases micropollutant levels of the Prut River in the downstream sector [29]. River ecosystems are exposed to chemical pollution, which raises further concerns about food contamination [30]. In Eastern Romania, water pollution concerns are also highlighted in the case of lakes from Iasi and Botosani counties [31], or from the Siret river near Pascani [32]. Massive diffuse pollution sources are attributed to localities without proper connection to WWTPs and with unsound management of sewage sludge, which affect groundwater resources [23,33]. Nitrate pollution of soil and groundwater sources poses serious public health threats across rural communities. Sewage sludge disposed without prior treatment contributes to GHGs emissions, while energy recovery through biogas production and co-generation could be a feasible solution at the county level [34].

3.2. Linear Economy in Agriculture

Intensive or subsistence agriculture based on chemical fertilizers and pesticides, and the improper management of food, agricultural wastes, and livestock wastewaters are still the norm in Romania. These actions favor the nitrate pollution of groundwater and rural communities are most exposed to these threats [35]. High amounts of organic waste are either illegally disposed or burnt in open spaces, or are poorly managed in composting processed by rural households. In this context, potential resources are lost as organic wastes under the "business as usual scenario", which disregards the environmental impact of agriculture on the local environment, following linear economy mechanisms [36]. Open manure dumps located near the agricultural lands are also sources of nitrate pollution for soil and water bodies.

Rural households and small-scale farmers lack access to manure waste platforms and liquid waste containers. In the case of larger farms, such facilities must be upgraded [33]. Chemical fertilizers prevail in agricultural practices and oftentimes the organic fertilizers used are not composted [37]. Both the composting process and manure management system must be improved to reduce the nitrate pollution associated with poor agricultural practices.

3.3. Linear Economy and Environmental Conflicts: Pungesti Shale Gas Case (Vaslui County)

The linear economy is based on the fossil fuel industry and on traditional mining activities which are detrimental to climate change policies. The EU supports the transition to the renewable energy sector. However, shale gas prospects were made in several places in Romania, including in Eastern Romania, to evaluate the shale gas deposits [38,39]. The risks involved by such exploitations in the long term led locals of the Pungesti commune and civil society to protest on 14 October in 2013 (150 people) and on 16 October, 500 people protested against this exploitation, blocking the road between Vaslui and Garceni [40]. The exploitation activities were temporarily stopped. Conflicts between private companies supported by local and national authorities versus locals escalated in December 2013, covered in national and international media [41]. Despite the fact Chevron had all authorizations to start the shale gas exploration with governmental support, the civil protests supported by several environmental NGOs tried to force Chevron to cancel further exploration activities. The Pungesti movement was supported also by street manifestations in the largest cities (Bucharest, Iasi, Cluj, and Timisoara), fed by force intervention of authorities in favor of Pungesti shale gas exploitation and against locals' concerns. In Vaslui county, such protests continued in 2014, while Chevron led only one successful exploration of shale gas deposits at around 3000 m depth. In February 2015, the company aborted the shale gas exploration projects in Romania, as well as in Bulgaria and Poland, claiming economic reasons. The company had environmental permits to explore shale gas deposits in the Paltinis–Balcesti, Popeni–Gagesti, and Puieti localities [42]. The Pungesti exploration platform was closed and adjusted to be used as agricultural land.

Community and environmental NGOs are opposed to traditional mining activities due to long-term environmental repercussions. Solar and wind energy sources are non-conflictual sustainable alternatives compared to the exhaustive use of hydraulic fracturing technology [38]. The renewable sector could help small and medium-sized businesses in giving opportunities for clean energy providers, which would support local economies.

4. Water Resource Usage in the Siret–Prut Hydrographic Network

4.1. Water Resources in Eastern Romania

The total surface of the hydrographic space between the rivers of Siret and Prut is over 25,800 km^2 (8.63% of the surface of Romania). The entire hydrographic network comprises a number of 392 rivers with a total length of 7696 km and an average density of the hydrographic network of 0.38 km/km^2. The rivers with permanent flows have a total length of 2269 km (representing 29.48% of the total watercourses) and those with temporary flows have a length of 5427 km (70.52% of the total watercourses). In combination with these, freshwater resources amount to 80 natural and anthropic lakes with an area of more than 0.5 km^2, and there are 262 ponds (most with areas of less than 0.5 km^2 [43]. The total volume of the water transported by the river network is estimated at 3700 million m^3.yr^{-1}, which can be used in an economy of approximately 960 million m^3.yr^{-1} (25.9%). The average multiannual flows for the main rivers in the region are 105 m^3/s for the Prut river (3300 million m^3. yr^{-1}), 11 m^3/s for the Barlad river (347 million m^3/year), 10 m^3/s for the Jijia river (316 million m^3/year), and 1.7 m^3/s for the Baseu river (54 million m^3/year). These represent 94% of the usable water volume within the surface resources, which is added the volume of usable water within the accumulation of lakes, with a total volume estimated at 615 million m^3 [44]. Groundwater resources are estimated at 251 million m^3, from which 35 million m^3 are from groundwater sources and 216 million m^3 are from deep sources. They are stationed in seven groundwater bodies (six developed at the national level and one cross-border with the Republic of Moldova) [45]. Most groundwater bodies have been delimited in the floodplains and terrace areas of the main rivers that drain the surface of the region (Prut and Barlad), as well as are located close to the land surface and are subject to anthropogenic pressures both quantitatively and qualitatively [46]. If we calculate the total volume of usable water to the population of the region, which is estimated at 2.2 million inhabitants at the usable water volume, we obtain 480 m^3.inhab.yr^{-1} and the specific resource calculated according to the theoretically available volume (multiannual average) is calculated at 2075 m^3/inhab.yr^{-1}. Practically, according to this analysis, the water resources located in this region can be considered as reduced, compared to other regions of Europe, and unevenly distributed in time and space.

4.2. Water Resource Usage by Population and Economic Activities

Regarding the actual water abstractions for various economic activities, they were analyzed at the level of economic sectors for the course of 5 years. The smallest volumes of water (surface and groundwater) were taken for the livestock sector, with average values of 2.5 million m^3 annually (0.5% of the total average annual water volume taken). The largest volumes of water taken were destined for various sectors of activity in the industry, with average volumes of 155 million m^3 annually (33% of the total average annual water volume taken). At the level of the entire region, water abstractions amounted to an average of 468 million m^3 per year, with quite wide variations in recent periods due to the natural conditions as well as the social and economic dynamics of the population in the region (Figure 2).

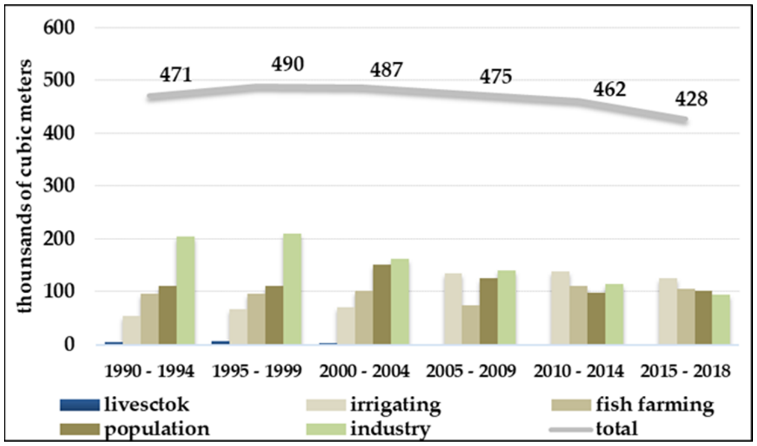

Figure 2. Water sampling in the eastern part of Romania by activity sectors in the period 1990–2018. Data source: Water Basin Prut–Barlad Branch.

After 2000, there is a general downward trend in the volumes of water taken due to the low demand from industry amid a rather sharp economic decline in the region (from 210 million m^3 in 1995–1999 to less than 110 million m^3 in 2015–2018). At the same time, there was a strong migration of the population from this region to other regions in Romania or Europe, with the effect of reducing the volumes of water taken to supply water to the population, in parallel with the expansion of water supply networks in urban areas but especially in peri-urban and rural areas. These water supply networks, fed from groundwater or surface water resources from adjacent drainage basins to this region, located in the western part beyond the Siret river, had the effect of reducing the volumes of water taken directly to supply the population with water resources in this region (from 151 million m^3 in 2000–2004 to 102 million m^3 in 2015–2018). However, 50% of the population of this region continues to be fed directly through individual wells [47], with an effect on the volumes of water taken.

4.3. Water Exploitation Index

Based on the official data published by EUROSTAT [48], it emerged that in Romania, a relatively low stress/deficit was identified at the level of groundwater resources and the WEI index had an average value of 10.2%. Conversely, for renewable freshwater resources and surface water resources, the average value of the WEI index was 20.1% and 23.3%, respectively, indicating the existence of high anthropogenic pressure on these water resources. The average of the three indicators at the level of the whole country was 17.9%, with an obvious tendency of decrease in the case of groundwater resources and a slight increase at the level of the last decades for both renewable water resources and surface water resources as shown in Figure 3.The methodology associated with the WEI + index was also applied for the eastern part of Romania. The whole region was divided into river basins corresponding to the typologies proposed by the EC 2000 Framework Directive [49] and for each basin, WEI + values were estimated. The results obtained illustrated, as depicted in Figure 4, a difference from those at the national level, taking into account the natural conditions and the demographic background specific to this region.

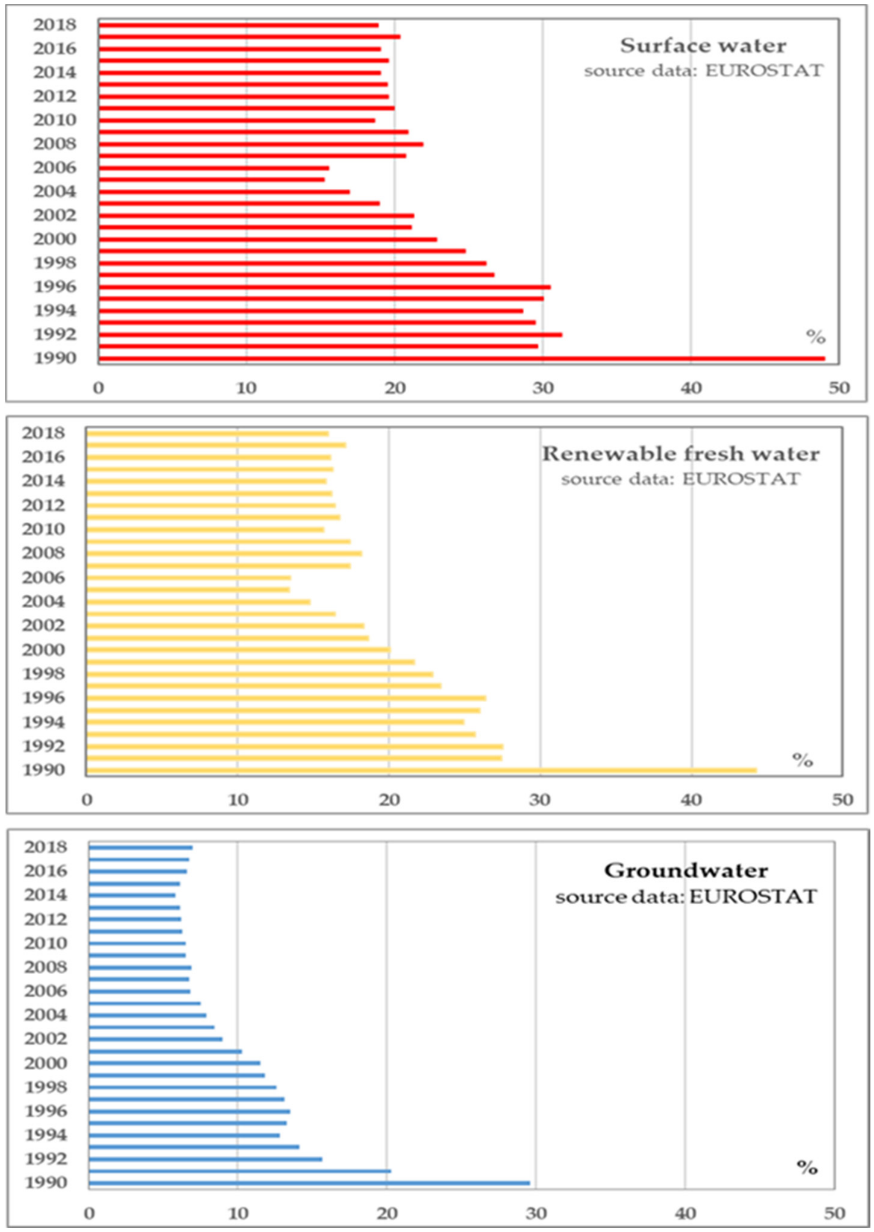

Figure 3. Evolution of the WEI index for different water resources in Romania between 1990 and 2018.

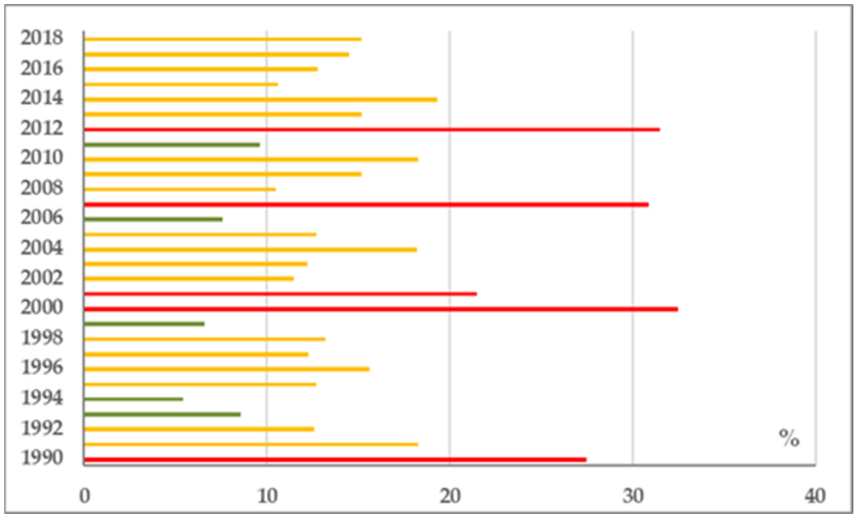

Figure 4. WEI + values in Eastern Romania between 1990 and 2018.

In dry years, the volumes of water available both from the surface and from the ground decrease considerably in the whole region. In this context, at the level of the entire region, the WEI + values in the period between 1990 and 2018 varied between 5.4 (1994) and 32.5 (2000), with a slight growth trend in the last two decades.

The highest pressures on water resources were in the dry years (2000, 2007, and 2012), in which the values of the WEI + index were over 30. Within the analyzed period of 29 years, 5 years (17.2%) indicate the existence of high anthropogenic pressure on water resources in this region and 19 years (65.5) indicate moderate pressure. The average value of the WEI + index was 15.6, indicating a relatively low pressure on water resources, but with potential for growth in the coming years due to anthropogenic pressure on groundwater resources as well as due to the direct effects of climate change on surface water resources [50–52].

5. Sustainable Alternative Routes to the Linear Economy and Resources Degradation

5.1. Circular Mechanisms in Regional Waste Management Systems

Integrated waste management systems provide basic infrastructure to source-separated collection schemes and waste treatment facilities such as sorting stations (dry recyclables), composting facilities, crushing stations (construction and demolition waste), mechanical–biological treatment (MBT) plants, transfer stations, and regional sanitary landfill sites. These facilities must cover both urban and rural communities. Each county is divided into several areas served by a particular waste operator. The key component of the regional waste management system is to ensure the population reliable waste collection schemes to eradicate open burning and illegal dumping practices, particularly in rural areas.

The triggering of waste diversion from urban landfills and the generating of efficient source-separated collections of main waste categories must be ensured by the population, by economic agents, and by public institutions. Each of these should enforce the following: (i) higher capture rate of dry recyclables (plastics, metals, glass, paper/cardboard, and wood); (ii) separate collection of biowaste under the new compost law, which entered into force on 20 February 2021 [53]; (iii) separate collection of the hazardous fractions of the municipal waste stream and bulky items; (iv) separate collection of e-waste; (iv) separate collection of construction and demolition waste; (v) separate collection of batteries and accumulators; (vi) collection and treatment of end-life vehicles (ELVs); (vii) separate collection of textile wastes; and (viii) separate collection of used tires.

Under the circular economy, these waste fractions are secondary materials that could feed a wide range of industries rather than being used for the extraction and processing of raw natural resources. The CE plan imposes the EU Member States to implement dedicated source-separated waste collection schemes to provide a sufficient amount of secondary materials for industrial and agricultural activities.

Urban mining represents a great opportunity to recover precious materials from several waste fractions such as e-waste, end-of-life vehicles, batteries, and accumulators, or construction and demolition waste. These fractions have a higher recycling/recovery potential and could limit the dependency of industries on traditional mining activities. However, collection and recovery of these waste flows are still limited in eastern Romania, with some progress made concerning end-of-life vehicles and e-waste.

Financial incentives could stimulate the urban mining process of special waste streams. The Government of Romania supports the renewal of the national car park by granting scrapping bonuses through the "Rabla" program [54], which also influences the yearly ELVs statistics in terms of the items collected and treated at the county level. Thus, the number of treated ELVs increased in 2018 compared to previous years, reaching 2336 (Iasi county), 1905 (Galati county), 889 (Botosani county), and 695 (Vaslui county)treated ELVs. However, some ELVs collected in a county could be treated in a facility from another county; therefore, caution is required in the comparative analysis between counties.

A positive trend is seen for e-waste fractions in which special collection schemes are put in place in urban areas and some e-waste collection campaigns are organized in both smaller urban areas and rural regions. The e-waste collection rate increased in Botosani county from 0.132 kg.per.capita.yr^{-1} in 2015 to 2.58 kg.per.capita.yr^{-1} in 2018, with some collection points located in rural communities beside the larger urban areas, but the collection rate is still low [55]. For Galati county, the e-waste collection rate ranges between 0.4 and 1.8 kg.per.capita,yr^{-1} in 2014–2018, with insufficient collection centers [25]. Special e-waste collection points are available in some districts of Iasi where the population can dispose of their e-waste items. Batteries, accumulators, and other e-waste items are collected from the population through shops and retailers in urban areas. In Vaslui county, there was only one economic agent authorized to treat e-waste fraction but their activity was suspended between February 2016 and February 2019; therefore, the e-waste collected was treated in other counties [23]. However, the development of e-waste collection schemes must be further supported in all urban areas of eastern Romania, combined with special e-waste collection campaigns for distant rural communities [56].

Additionally, collection schemes for hazardous municipal waste and bulky items are missing in eastern Romania, except in Iasi, which has a modern municipal waste collection center where all household waste items can be collected and in two collection points in Galati. Iasi also started a source-separated collection of old clothes and textile wastes from the population through dedicated containers placed in some districts.

Over 90% of the used tires collected in Romania feed the cement factories as a substitute for fossil fuels and a small proportion are recycled in the form of rubber powder, which is further used in various applications [20]. However, material recycling should attract more interest in improving circularity compared to the energy recovery option, which raises air pollution concerns.

Construction and demolition waste could feed the construction industry with recycled aggregates or raw materials for the cement industry rather than using natural resource extractions from land or water bodies (e.g., gravel pits). However, this emerging waste stream seems neglected by local authorities. Cheap natural aggregates and the lack of crushing plants in every county favor the landfill or illegal dumping of this emerging waste stream in Romania [57]. There are no operational crushing plants and storage facilities in the Botosani, Iasi, and Vaslui counties for C&DW fraction, despite increasing amounts of this waste stream in the last decade, particularly in Iasi. The county waste management plan of Iasi county emphasizes the necessity of such facilities near transfer stations or regional sanitary landfills [58]. For example, 25,288 t C&DW was collected, of which 7600 t derived from the population, but most was disposed of in the Tutora regional sanitary landfill site. In Galati county, there are two authorized companies with crushing plants at which C&DW is treated and the secondary materials are used for concrete aggregates or backfilling materials [59]. Both crushing plants are located near Galati city and most of the localities are not served by such facilities. In Botosani county, part of C&DW (around 3000 t) was used as backfilling [55].

Figure 4 reveals that biodegradable fractions have the highest ratio of MSW composition in Eastern Romania. Data regarding waste composition are based on waste operators' estimations and are centralized by local environmental agencies at the county level. The data are not broken down to urban and rural communities, except in the case of Iasi county. In the latter case, rural–urban data reveal a higher share of biowaste fraction in rural communities (64%) compared to urban areas (47.15%) as well as fewer post-consumer packing materials (paper cardboard, plastic, and glass). The highest ratio of paper-cardboard (12–13%), plastics (11–12%), and metals (around 5%) were in the Botosani and Vaslui counties. The maximum biowaste (66.33%) was found in Galati county, even above the rural Iasi.

However, these estimations must be validated by several experimental studies of waste composition in each urban area and by samples from rural communities to improve the current data. The new regional waste management plans for 2019–2025 fail to provide municipal waste composition data based on field measurements in Eastern Romania.

In Botosani county, the recycling rate of the municipal waste stream decreased from 18.24% in 2014 to 1.66% in 2018 due to dysfunctions of the source-separated collection schemes under the new waste management system which replaced the old economic operators [60]. In Vaslui county, material recycling was estimated to be around 4% in 2017 and 96% of the municipal waste flow was landfilled without energy recovery facilities [13]. The sorting station from Rosiesti is operational since January 2020, with a capacity of 14 500 t/yr^{-1} for paper and cardboard, and 14 000 t/yr^{-1} for plastics and metals, but there are no recycling facilities in the county [24]. Separate collections of recyclable and biodegradable waste streams are implemented on a small scale in Galati county (one city + five communes) [61] and most of the localities do not have access to the treatment facilities. The capture rate of dry recyclables is low (around 4%) because only Galati is served by a sorting station since 2020 and 96% of the municipal waste is landfilled at the county level [25]. A better situation can be seen in Iasi county in which the capture rate of dry recyclables is around 11% and two sorting stations (Tutora and Harlau) are operational since 2013 [58].

The shift from non-compliant landfills and older waste operators to new regional integrated waste management facilities (sorting and composting plants, transfer stations, and regional sanitary landfills sites) with new authorized waste operators is changing the regional waste management market in Eastern Romania. However, this process varies from one county to another, which undermines the circular mechanisms (composting, material recycling, and bioenergy from waste treatment) in the study area. Additionally, the current delays in operating such facilities and the gaps in waste statistics make it difficult to conduct an in-depth comparative analysis between these four counties.

5.2. Sustainable Wastewater Treatment Facilities and Water Resource Usage

Access of the population to the public water supply increased in the study area from 1.070 669 people in 2010 to 1.157.928 inhabitants in 2018, but only 809.723 were served by tertiary stage WWTPs. The extension and modernization process of wastewater treatment plants as well as the connection of urban and rural localities to sewage systems are crucial processes in eastern Romania. Municipal wastewater treatment plants cover mainly urban population of counties as shown in Table 2.

Table 2. Wastewater treatment plants' coverage in Eastern Romania.

Country	Resident Total Population (Number) 2018	Urban Population	Public Water Supply Connection	WWTP Connection	WWTP Tertiary Stage	Sewage Connection with No Treatment
Botosani	385,268	157,324	140,542	110,640	104,215	7162
Iasi	791,753	366,667	460,296	320,773	310,892	-
Vaslui	379,987	155,118	147,504	123,187	73,907	108
Galati	510,865	277,997	409,586	321,690	320,709	5550

Data source: National Institute of Statistics.

Populations served by sewage systems without treatments must be connected to tertiary stage WWTPs (Botosani and Galati). Secondary WWTPs (Iasi and Galati) must be upgraded to tertiary WWTP to provide better protection of water bodies. Crucial investments are needed in Vaslui and Botosani counties, as recognized by development strategies and environmental reports. In such counties, the urban population cannot fully access the public water supply.

This situation derives from smaller urban areas with dominant rural features and villages that are annexed to urban local administrative units (LAU), which rely on wells. The extension of public water and wastewater infrastructures are under implementation in urban areas of Botosani county and in eight communes through an EU-funded project [62]. A similar project is managed by Apavittal in Iasi county where 191,292 inhabitants will receive coverage by better water supply facilities and 77,188 by improved WWTPs [63]. Galati is the only county in Romania in which tertiary stage coverage of WWTP is above that of the urban population, compared to Vaslui county in which around half of the urban population is connected to such facilities.

Sewage sludge resulting from such facilities could be used in agriculture after further treatment (composting or anaerobic digestion), including for application in degraded lands or in the bioremediation of contaminated sites by organic pollutants [64]. However, sewage sludge could contain toxic chemicals for the environment. Experimental analysis of heavy metals' concentration in sewage sludge resulting from Galati urban WWTPs showed values below national limits [65]. Such investigations are necessary to detect and monitor potential risks associated with agriculture applications. In contrast, some of the wastewater indicators were above the legal limits in the same city [66]. Furthermore, the use of treated sludge as fertilizers for agricultural lands depends on the soil conditions from each county [55]. The application of sewage sludge in agriculture must be improved in the short, medium and long term due to the landfill restrictions imposed by EU regulations and for the purpose of increasing the circularity of sludge flow as follows [25]: (i) in short-term (until 2023) landfilling (90%) and agricultural use (5%); (ii) in medium-term (2024–2034) agricultural use (60%), landfilling (30%) and in incineration with energy recovery (5%); (iii) in long term (starting from 2035) agricultural use (>65%), at the closing of landfills, for reforestation, for soil improvement of degraded lands (15%), and to avoid landfilling as much as possible. Systematic monitoring of both wastewater and sewage sludge is required in each WWTP in the study area to control and reduce pollution as well as to safely feed circular mechanisms.

Sustainable wastewater management practices should replace direct discharges of untreated wastewater into water bodies and should reduce GHG emissions from the water sector [67]. Some water systems in Romania have water losses of more than 50% of the total water extracted with higher energy demands [68]. Therefore, the improvement of water capture, transport systems, and the optimization of energy demand are required in the water supply sector [69]. Reuse of treated wastewater is regarded as an emerging nonconventional water resource apart from desalinated seawater or the direct use of agricultural drainage water [3]. In Romania, vineyards could be irrigated from the wastewater of wineries [70] and solutions to reduce water consumption demands must be further developed in the wine sector [71]. Advanced treated wastewater from livestock farms could be used in similar agricultural applications [72]. On-site or decentralized domestic wastewater facilities using nature-based systems reveal promising results in some touristic rural communities (Vadu Izei and Mara) of Maramures county [73]. Such approaches could be used also in eastern Romania to develop a sustainable agritourism sector. However, Eastern Romania needs critical investments in water and wastewater infrastructure. The regional development targets related to public utilities that was set up for 2027 in Vaslui county include [13]: (i) connecting 65% of the resident population of the county to water supply networks; (ii) connecting 50% of the resident population of the county to sewerage networks (iii) establishing 50% of selective waste collection; and (iv) modernizing 72% of the roads in the county. Therefore, the full coverage of the population (urban and rural) towards public utilities must be achieved as soon as possible, with additional governmental support for less developed regions.

5.3. Centralized or Home Composting Practices and Small-Scale Organic Farming

The transition from subsistence agriculture to small-scale organic farming businesses must be supported in eastern Romania as a key sustainable development route. Enhancing home composting practices in rural areas under the implementation of the regionally integrated waste management system is compulsory considering biowaste is the main waste stream in rural and urban communities of eastern Romania, as shown by Figure 5.

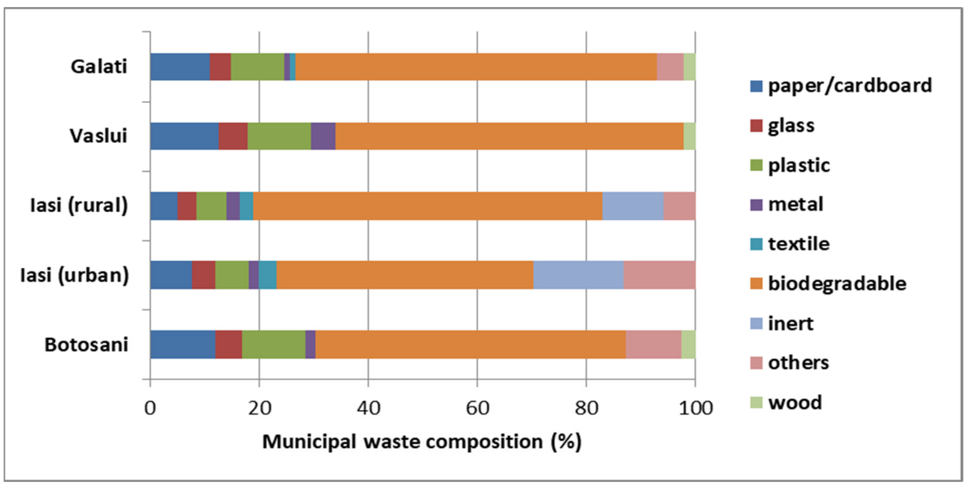

Figure 5. Municipal waste composition in Eastern Romania (data based on waste operators' estimations from environmental reports).

Home composting of biowaste (food waste and agricultural waste) must play a key role in the waste diversion of biowaste from landfills, wild dumps, or open-burning practices. However, the traditional method of composting (piles on open land) must be replaced with improved and controlled techniques [36]. Therefore, individual composting units and bins should be provided to all rural households for home composting practices. The regional integrated waste management systems include the acquisition of individual composting units or bins for source-separated biowaste collection, as shown in Table 3.

Table 3. Biowaste facilities provided by regional integrated waste management systems or future investments options.

County	Composting Plant (CP) Capacity (t.yr.$^{-1}$)	Home Composting Facilities	TMB with Anaerobic Digestion
Botosani	Option: 3 CP (1300 t.yr^{-1})	Target: 22,960 composting units, full coverage	Option: MBT 36,000 t.yr^{-1} (start in 2023) and anaerobic digestion (22,000 t.yr.$^{-1}$) target 2022

Iasi	CP Tutora (10,000 $t.yr^{-1}$), non-operational in 2019; feedstock green-waste from gardens, public parks, and spaces	Target: 31,971 composting units (280 l) covering 25% of rural households	MBT Tutora (148,500 $t.yr^{-1}$): non-operational in 2019
Vaslui	-	19,505 composting units in rural areas and 5295 in suburban areas	-
Galati	CP Galati City(10.000 t.yr) CP Targu Bujor (200 $t.yr^{-1}$), not operational CP Tecuci (700 $t.yr^{-1}$), new investment	Source-separated collection in rural areas (starting in 2021)	Option 1: MBT with anaerobic digestion plant (120,000 $t.yr^{-1}$) Option 2: anaerobic digestion plant (48,000 $t.yr^{-1}$) + WtE plant (120,000 $t.yr^{-1}$)

Data source: [24,58,61].

The environmental report stipulates that 50% of the municipal waste generated and uncollected is assumed to be treated through home composting practices in Botosani county [60]. Traditional biowaste recovery through home composting and animal feed must be upgraded in terms of environmental protection measures and must be further promoted among rural communities. The new composting law requires local authorities (urban and rural municipalities) (i) to introduce source-separated collection schemes for biowaste fractions of municipal solid waste flows (door to door or collection points); (ii) to introduce financial incentives such as "pay as you throw"; and (iii) to support home composting initiatives in rural communities [53].

Despite the fact the regional waste management plan stipulates as a key objective the use of compost and digestate in the agriculture sector, starting with 2020, there is a small composting unit in Botosani county, and the home composting process is poorly monitored [55]. There are some incentives to raise the farmer′s awareness regarding the use of sewage sludge as a reliable natural fertilizer but with limited impact so far. There is no data on the efficiency of home composting practices in Vaslui county regarding the individual composting units (280 l) shared with rural and suburban populations, and a permanent awareness campaign should be performed among rural communities [24]. The biowaste treatment facilities were not operational in Iasi county; however, the regional waste management plan stipulates the implementation of at least one awareness campaign each year regarding the use of compost/digestate in agriculture [58].

There is no data on the efficiency of home composting practices in Vaslui county regarding the individual composting units (280 l) shared with rural and suburban populations, and a permanent awareness campaign should be performed among rural communities [24].

The biowaste treatment facilities were not operational in Iasi county; however, the regional waste management plan stipulates the implementation of at least one awareness campaign each year regarding the use of compost/digestate in agriculture [58].

According to the compost law [53], the compost and digestate resulting from the biological treatment of biowaste are broken down into the following qualitative categories: (i) A, which is compost/digestate of high quality that can be used in agriculture/horticulture; (ii) B, which is good quality compost that can be used as fertilizer in green public spaces (urban and rural communities); and (iii) C, which is low quality compost/digestate, requiring further improvement treatment under technical guidelines.

The compost resulting from green waste (198 tons in 2019) in Botosani was used as fertilizer for public parks and green areas, but most of the biowaste is landfilled at the county level [55]. A similar situation is seen in Galati, in which 5.936 t of compost was produced between 2015 and 2019 and used as fertilizer for urban green spaces or landfill cover [59]. Therefore, the application of compost in agriculture obtained in centralized composting facilities is almost non-existent in the study area. The link between compost and organic agriculture must be highlighted among farmers and decision-makers to develop a reliable compost market at regional and local scales, with benefits for both urban and rural communities. This aspect is crucial to increase the use of compost in agriculture, in accordance with EU requirements, but an effective source-separation of biowaste (low contamination level) is required. The use of balanced composted organic fertilizers in agriculture has positive implications in reducing GHGs [37].

There is an increasing interest for conversion from conventional to organic agriculture, as supported by compensatory aids through the National Programme of Rural Development with Botosani and Iasi in the top applications of the north-east region [74]. The development of organic agriculture supported by high-quality compost derived from the organic fraction of the municipal solid waste flow, the agricultural wastes (e.g., manure), and the digestate is a key pathway to increase the sustainable recovery of biomass. Therefore, the circular economy and organic agriculture can provide sustainable development alternatives in Eastern Romania if high-quality compost is produced and used both by farmers and the agri-food sector.

5.4. Expansion of Manure Management Platforms

Manure management is a crucial environmental challenge in agricultural and rural environments in Eastern Romania. Unsound manure management is a major widespread pollution source of rural households due to the poor infrastructure and subsistence agriculture prevalence in local economies. Sustainable agriculture aims to prevent soil and groundwater pollution through the proper management of manure generated by livestock. Community platforms began to be built in smaller urban areas and rural communities of the study area, as shown in Table 4 [75].

Table 4. Extension of manure platforms in Eastern Romania.

County	Locality (Urban/Rural)	Capacity (t)
Botosani	Stefanesti (U)	2000
	Sulita (R)	1200
Iasi	Cotnari (R)	
	Deleni (R)	2000
	Cristesti (R)	2000
	Mircesti (R)	2000
	Miroslva (R)	2000
	Voinesti (R)	2325 *2 (platforms)
	Mironeasa (R)	2000
	Scânteia (R)	2000
	Grajduri (R)	2000
	Ipatele (R)	2000
	Tibanesti (R)	-
	Mosna (R)	-
	Ipatele (R)	(in construction)
	Coarnele Caprei (R)	
Vaslui	Falciu (R)	1200
	Hoceni (R)	(in construction)
Galati	Tepu (R)	1200
	Fundeni (R)	2000
	Schela (R)	2000

Source: [75].

Some facilities were built in smaller urban areas which have villages in their administrative area, such as Stefanesti (Botosani county). Iasi county has the most manure platform projects from eastern Romania but more investments are required in rural regions of eastern Romania.

Both community and individual (household) manure platforms must use an impermeable base (concrete) with walls and the resulting effluents (including rainwater) must be collected to prevent soil and groundwater pollution with organic pollutants (e.g., nitrates). Individual platforms must be located at least 50 m away from households or drinking water supply stations (e.g., wells), and at least 500 m away in the case of intensive farming activities [76].

Community platforms must not be located (i) in flooding areas, (ii) near water bodies (at least 100 m distance), (iii) in areas where groundwater sources are less than 2 m in depth, and (iv) in the proximity of forest areas [76]. However, most of the rural municipalities in eastern Romania do not have access to proper manure management infrastructure (individual or community sites). The transition from subsistence agriculture to small-scale or medium-sized organic farming activities implies the sound management of agricultural waste flow and the use of high-quality compost or digestate as natural fertilizers by farmers within the community.

The National Rural Development Plan supports the development of organic agriculture and investments in bioenergy production feed by agricultural wastes and biomass residues [37]. Rural areas face serious environmental issues raised by the lack of sound manure management among rural households and the agri-food sector.

A special guide for ecological agriculture stipulates that the compost resulting from manure can be utilized as a natural fertilizer in line with the following criteria [77]: (i) manure must not exceed 170 kg N/ha for organic farming payment and must respect the calendar for such application, and (ii) manure resulting from animals exceeding the maximum allowable load livestock units (LSU/ha) must not be used as fertilizer for agricultural lands under agri-environment payment. However, the national rural development plan with the associated guideline for organic agriculture does not mention the use of compost based on the organic fraction of the municipal waste stream or sewage sludge from wastewater treatment plants. These alternatives must be further considered under strict quality monitoring procedures to increase the circularity levels of biomass resources through composting applications in agriculture. The development of a high-quality compost market should be a critical target for decision-makers.

5.5. Renewable Energy Sources and Biogas Production from Biowaste

The renewable energy sector in Romania has developed in the last decade particularly in terms of wind and solar sources [78,79]. This is also true for Eastern Romania, in which wind energy production is dominant, followed by photovoltaic power plants, as shown in Table 5.

Table 5. Renewable energy sources (wind, solar, and biogas) operational in 2020.

County	Wind Energy (MW)	Photovolatic Energy (MW)	Biogas (MW)
Botosani	0.099	3.029	
Iasi	9	5.248	
Vaslui	73.850	0.025	0.5
Galati	172.75	1.345	

Source Transelectrica [80].

The hydro energy source is provided by the Stanca–Costesti lake on the Prut river, where hydropower capacity is equally shared with the Republic of Moldova. The operational power of solar and wind energy will significantly increase in Iasi county (118 MW) after the connection of several energy producers to the national grid system [80]. There is only one renewable energy plant (biogas) based on biomass resources in Vaslui county.

The transition to renewables sources is imperative to support circular economy mechanisms. Biogas production, natural fertilizers, and reduced water consumption in the agricultural sector are key challenges to ensure sustainability goals in the long term.

In eastern Romania, Muntenia de Jos commune (Vaslui County) has the only operational biogas plant (capacity 15 MW per yr^{-1}), which produces biogas based on anaerobic digestion of biowaste-receiving green certificates for the renewable energy produced. The biogas is used through a co-generation plant to provide electric and thermal energy as shown in Table 6. [81].

Table 6. Biogas plant capacity, feedstock, and energy produced in 2018.

Biogas Production (Projected)	4000 m^3/per Day	Feedstock Used	2018
Methane gas (projected)	2400 $m^3.day^{-1}$.	Poultry waste (t/yr^{-1})	790,468
Electrical energy production (MWh in 2018)	2542	Wastewater (m^3)	2520
Thermal energy production (MWh in 2018)	3.64	Corn silage (t/yr^{-1})	4781.9

Source of data: [81].

The biogas is derived from the anaerobic digestion of agricultural wastes (poultry wastes), in combination with wastewater and energy crops (corn silage). The resulting digestate is used as a natural fertilizer in agriculture. The biogas reuses wastewater as feedstock in the anaerobic digestion process, reducing water resource consumption. These circular mechanisms, such as bioenergy production (biogas), natural fertilizer (digestate), and the reuse of wastewater, should be further promoted in similar facilities.

Despite the high potential of the biogas sector, this renewable energy source is still underdeveloped in Romania [82,83]. Collaboration between livestock farms and biogas plants must be supported by regional and local authorities in each county of Eastern Romania. To increase the circularity levels of biogas plants, agricultural and organic fractions of municipal solid waste should be the main feedstock as opposed to energy crops. In the latter case, expansion of energy crops for biofuel production could have negative impacts on food production in Romania [84]. Therefore, the biowaste diversion (municipal and agricultural sources) from landfills to biogas production is a feasible solution in the agricultural sector, taking into account the biomass resources of Romania and the high organic ratio of the municipal waste stream, as shown in Figure 4.

In Botosani county, there are three economic operators, which use biomass residues (sawdust, wood waste, vegetal residues) in energy recovery plants (Stiubeni and Frumusica communes), and one facility in Botosani. Such energy recovery plants should be fed strictly by agricultural wastes (e.g., sawdust and wood wastes), with a pertinent monitoring procedure for a country such as Romania which faces deforestation and significant illegal logging activities. Additionally, the bioenergy sector should focus on biogas production and co-generation facilities (electric and thermal energy production) fed by biowaste flow (organic fraction of MSW, manure, and sewage sludge).

The extension of the sewage and water supply in eastern Romania will be a critical investment in the following years; therefore, the amount of wastewater is expected to increase. Romania must divert the biowaste from landfills according to EU legislation, while the larger flow of sewage sludge must be safely managed due to the coverage expansion of WWTPs. The resulting sludge could be further treated by anaerobic digestion or composting methods, or as a last option in mechanical–biological treatment plants prior to landfilling (MBT). The biogas production would provide a degree of autonomy concerning fossil fuel energy demand. As an example, the biogas plant from the wastewater treatment of Iasi covers about a third of the annual demands of electrical energy, obtained through co-generation and 80,000 lei of economic savings per month [85].

The MBT facility of Galati city will have a sorting line and anaerobic digestion plant with a co-generator to produce electricity [86]. Another innovative solution is the use of biogas derived from sewage sludge (urban WWTP), combined with photovoltaic installation to feed the tourism sector with clean energy, such as in seaside hotels [87]. Clean energy sources, responsible water consumption, source-separation of waste, composting, and organic farming are all steps to provide sustainable rural agri-tourism development in Eastern Romania.

5.6. Zero-Waste Policies in the Agri-Food Sector

Food waste diversion from landfills is crucial to reduce GHG emissions related to the waste sector for a country such as Romania in which organic waste fraction is the most prevalent in MSW flow, in addition to outputs from the agri-food sector.

Centralized composting and anaerobic digestion plants are the main options at the industrial and urban levels, followed by home composting practices and animal feed in rural communities. Source-separated collection schemes of food waste are not yet available in eastern Romania and only a separate collection of green waste is performed in some urban areas. The Social-Trading Urban Place organization initiated the "Uleiosul", which is an urban project for the collection of edible oils and used fats in Iasi city. The collection is free of charge but a minimum quantity of four liters (individual) and 20 liters (economic agents) is required [88]. Zero-waste strategies imply a holistic approach to preventing and reducing food waste generation at the producer and consumer level [89]. The Food Waste Romania and Foodwastecombat project aim to raise awareness among decision-makers and the population concerning food waste issues and how to reduce this biowaste flow at the household level [90,91]. Responsible shopping is required for reducing food waste generation in households [92]. The know-how exchange between entrepreneurs from the EU could stimulate the progress of circular activities in the agri-food sector [93].

In Eastern Romania, the "Mai Bine " Association (Iasi) is the leading organization in implementing zero-waste strategies related to the agri-food sector. Thus, the main objective of CUIB is to become both the first Romanian bistro to be zero-waste-certified and the first zero-waste shop from Iasi (including eastern Romania). This achievement is based on reducing practices and reuse options, with a low ecological footprint [94], including strategies such as: no single-use plastic packaging materials; encouraging the use of local products (food and beverages); promoting vegetarian food; offering free tap water; establishing a food waste bank; composting; and organizing small-scale organic farming (CUIB Iasi).

This approach could be further implemented in other similar projects in Botosani, Vaslui, or Galati counties. Such initiatives would strengthen the urban–rural relations in the agri-food sector with benefits to local economies and the environment.

6. Conclusions

The paper revealed the linear economy contributions to environmental pollution and resource degradation in Eastern Romania through unsound waste, wastewater, and water management practices, as emphasized in Section 3. Exploitation prospects of natural resources also led to environmental conflicts in the study area (e.g., Pungesti shale gas) due to the environmental concerns of the community.

The highest pressures on water resources were in the dry years (2000, 2007, and 2012) in which the values of the WEI + index were over 30. Of the analyzed period of 29 years (1990–2018), 5 years (17.2%) indicated the existence of high anthropogenic pressure on water resources in this region, while 19 years (65.5) indicated a moderate pressure (Section 4). Water resource usage and wastewater are expected to increase in the following years due to both the expansion of the public water supply and the connection of small cities and rural communities to WWTPs. Therefore, water conservation measures by industrial and agricultural sectors are required.

The expansion of manure management platforms and wastewater systems in rural communities are critical factors in reducing organic pollution in the air–water–soil nexus. Bioenergy production based on biowaste is still limited despite the high organic content of municipal and agricultural waste as feedstock in Eastern Romania. Few operating compost facilities indicate the loss of biomass resources through landfilling in urban areas, through illegal dumping, and through open-burning practices in rural communities.

Compost produced at urban facilities is often used as fertilizer for urban green spaces or as landfill cover rather than being used in agriculture.

The delays in developing centralized composting facilities and anaerobic digestion plants in urban areas, as well as the inadequate monitoring of domestic composting practices in rural areas, pose a real challenge in meeting the target for diverting biowaste from landfills as part of the circular economy supported by the EU.

Sorting, composting, and crushing plants should serve every city, town, and surrounding rural communities to catalyze the regional circular mechanisms as well as to provide reliable secondary materials for industry and natural fertilizers for agriculture. Lack of crushing plants to treat the emerging C&DW stream favors the exploitation of natural aggregates from river ecosystems. Despite some waste management infrastructure development, the capture rates of dry recyclables and e-waste flow are still low in Eastern Romania, which undermines the progress of material recycling activities. Source-separated collection schemes for populations must be improved in all urban and rural regions, coupled with environmental awareness campaigns.

Six non-conflictual and sustainable development alternative routes are proposed for Eastern Romania (Sections 5.1–5.6) to improve resource recovery levels for recycling industries, for water conservation, and for organic farming development. The biogas production from agricultural waste or sewage sludge, the reuse of treated wastewater, and the application of compost/digestate in agriculture are some of the best practices identified at the business and community levels, which must be further expanded upon in Eastern Romania. Zero-waste business models in the agri-food sector (e.g., CUIB Iasi) are the ultimate goals for circular economy initiatives in managing the food waste crisis. The circular initiatives combined with water conservation strategies must be further supported by decision-makers in both urban and rural communities to limit the environmental pollution and resource degradation in Eastern Romania.

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